Pertanika J. Trop. Agric. Sci. 48 (1): 117 - 136 (2025)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Sequential Cropping Productivity Evaluation of Corn, Mung Bean, and Sweet Potato Intercrop under Coconut Field in Zamboanga del Sur, Philippines

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ABSTRACT

Multiple cropping and sequential cropping system strategies with existing perennial crops would augment soil productivity per unit area, which optimizes crop production for food security. The study evaluated the effects of cropping patterns on the agronomic and yield performance, total productivity and profitability of corn, mung bean, and sweet potato planted under coconut ground in Zamboanga del Sur, Philippines. There were eight cropping patterns (CP) [(CP_1—corn followed by mung bean), (CP_2—corn followed by sweet potato), (CP_3—corn intercropped with mung bean followed by sweet potato), (CP_4—corn intercropped with sweet potato followed by mung bean), (CP_5—mung bean followed by corn), (CP_6—sweet potato followed by corn), (CP_7—mung bean followed corn intercropped with sweet potato), (CP_8—sweet potato followed by corn intercropped with mung bean)] arranged in Randomized Complete Block Design (RCBD). The results revealed that growing in a cropping pattern relative to the cropping period affected the days of tasseling and silking, plant and ear height, percent shelling, weight of 1000 seeds, and grains of corn. Sole corn and mung bean intercrop showed the same results, while Corn + Sweet potato intercropping decreased plant height and grain yield in corn regardless of the cropping pattern. Mung beans are affected by the cropping season in terms of the days of flowering, maturity, plant height, weight of 1000 seeds, and yield. Sweet potatoes showed the best performance in a number of lateral vines, maturity, and yield when placed first in the cropping pattern. However, sweet potato intercropping resulted in a reduction in yield. Further, CP_6-sweet potato, followed by corn, had a notable total yield with a 98% return on investment and as a recommended intercropping pattern under coconut ground in the area.

Keywords: Agroeconomic crops, cropping pattern, crop placement, intercropping, productivity

ARTICLE INFO

Article history:
Received: 22 April 2024
Accepted: 24 July 2024
Published: 28 January 2025

DOI: https://doi.org/10.47836/pjtas.48.1.07

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ISSN: 1511-3701
e-ISSN: 2231-8542

INTRODUCTION

The global demand for food, as a result of the growing population, denotes more ample solutions and intensification in agricultural production to ensure food security (Lirio et al., 2023). Declining agricultural production as a result of land conversion, climate change, and biodiversity considerations are just a few of the obstacles that need to be overcome to satisfy demands (Rondhi et al., 2018). A single crop used for mass production necessitates the excessive application of synthetic fertilizers and pesticides, which increases pollution, reduces agricultural diversity, and ultimately results in food insecurity (Smith et al., 2020). As those are part of the growing concern in agriculture, adaptability in crop diversification programs using multiple cropping systems may alleviate crop productivity and aggravate negative impact, loss of biodiversity, and crop losses due to climate effects (Hufnagel et al., 2020; Food and Agriculture Organization, 2001). The multiple cropping approach combines certain perennial crops with agronomic crops to increase crop productivity, income, and food supply, benefiting both economically and ecologically (Waha et al., 2020).

In concept, multiple cropping comes into many examples, such as intercropping, double cropping and crop rotation. However, one must understand the variety of techniques in cropping patterns, growing crops in succession in one field at a particular time, considering climatic factors (Negash et al., 2017). Further, crop rotation practice is planting a series of different crops right after the other with a short harvest period (Tariq et al., 2019). Intercropping practice is cultivating short-period main or cash crops like root crops or vegetables under tall perennial crops like coconut and fruit-bearing trees (Fan et al., 2020). The time, space and arrangement of crops in a particular land area would enable increased crop productivity, production efficiency, land use efficiency, and economic return (Castellazzi et al., 2008). Likewise, the practice of intensive cropping systems under perennials with sequential patterns and crop rotations is extremely important. It enhances sustainable system productivity by efficiently using resources like microclimate and nutrient dynamics (Amosse et al., 2014).

Undeniably, coconut is one of the most well-known permanent crops for export (Moreno et al., 2020) in the Philippines while simultaneously importing corn and rice (Davidson, 2018). Under these conditions, intercropping agroeconomic crops with sequential crop rotation and crop patterns will boost the land's economic value of coconuts and productivity instead of lone-produced crops and the income of coconut growers from coconut alone. In the Philippines, the primary coconut-producing regions include the Davao Region, CALABARZON, Northern Mindanao, and the Zamboanga Peninsula. Among these, the Zamboanga Peninsula ranks as the second-largest contributor to national coconut production, accounting for 13.6% of the total output. According to the Philippine Coconut Authority (2019), the region has a gross production spanning 1.747 million hectares. The intercropping system under coconut is an old practice of the local farmers with a continuous corn-corn-fallow sequential cropping pattern. Sowing usually starts in the first to the second week of April, and the crop is harvested in the first to the second week of August. It is followed by cultivating another batch of corn to be planted in the third to fourth week of September and harvested at the end of January. After harvesting corn, the land is allowed to fallow for one and a half months.

Thus, there was a need to explore a study on cropping patterns using some agronomic crops to be grown under coconut. This study evaluated the cropping pattern and placement of some agronomic crops, such as corn, mung bean, and sweet potato, planted under coconuts. The specific objectives were (1) to evaluate and determine the key performance parameters of agronomic crops planted under coconut conditions; (2) to evaluate the total productivity of the crops grown under coconut; (3) assess the profitability of growing some agronomic crops under coconut in different cropping patterns in Zamboanga del Sur condition; and (4) determine the best cropping pattern under coconut to be recommended to farmers in Zamboanga del Sur. The study results would give farmers insight into the maximization of space between coconuts through intercropping.

MATERIALS AND METHODS

Description of the Experimental Site

The study was conducted at Bagong Oroquieta, Guipos, Zamboanga del Sur. The municipality of Guipos is a landlocked coastal province of Zamboanga del Sur. It has a land area of 9,104.60 hectares, accounting for 2.01% of the Zamboanga del Sur's total area. The town is approximately 7° 44' North, 123° 19' East, with an elevation estimated at 151.5 meters or 496.9 feet above mean sea level. The total land area covered by coconut production in the municipality is 1,126.98 hectares out of the total area of the province. There are 1,350 farmers owning an area of less than 5 hectares in size. A total of 40,091 coconut trees are within three years of planting, 66,055 coconut trees are more than 3 to 60 years old from planting, and only 99 coconut trees are more than 60 years old.

Coconut areas in the locality are usually intercropped with agronomic crops such as corn, rice, sweet potato, cassava, mung bean, peanut and some vegetables. The most adopted cropping patterns are corn-corn-fallow, corn-legumes-fallow, rice-corn and corn-root crops. This study was superimposed on the existing coconut plantation approximately seven years after its establishment. The variety of coconuts planted has not been identified. These are grown at a planting distance of 10 x 10 meters. It was previously intercropped with corn for five successive years except for the last cropping year, 2018, when it was planted with mung beans for a short-term study.

Experimental Design and Treatments

The study was conducted in a 1,100 m^2 area under tall, statured perennial coconut trees and was prepared thoroughly. It was divided into three blocks, and each block was further divided into eight plots, with a dimension of 8m × 3.5m. The alleys between blocks were four meters, and between plots, one meter to facilitate operations in the field. RCBD with eight treatments replicated three times was used. The different cropping pattern (CP) treatments were as follows: CP_1—corn followed by mung bean sequential pattern (Corn-Mung bean). CP_{2-}corn followed by sweet potato sequential pattern (Corn-Sweet potato). CP_3—corn + mung bean intercrop followed by sweet potato (Corn + Mung bean-Sweet potato). $CP_{4_}$Corn + Sweet potato intercrop followed by mung bean (Corn + Sweet potato-Mung bean). CP_5—Mung bean followed by corn sequential pattern (Mung bean – Corn). CP_6—Sweet potato followed by corn sequential pattern (Sweet potato-Corn). CP_7— Mung bean followed by Corn + Sweet potato (Mung bean-Corn + Sweet potato). CP_8—Sweet potato followed by corn + mung bean (Sweet potato-Corn + Mung bean).

Cropping Period and Rainfall Data

The cropping period, comprising two seasons, started from September 2019 to March 2021. The first cropping was conducted from October 2019 to March 2020, and the second was conducted from May 2020 to March 2021. The rainfall data of the experimental area was taken to the nearest agro-meteorological weather station (Figure 1). The crops received total mean rainfall of 200.64 mm and 286.58 mm during the cropping period of 2019–2020 and 2020–2021, respectively. The month of June 2019 received the heaviest rainfall record and regularly decreased until the end of the cropping season. On the other hand, more than 70% of the rain was received on the second cropping from May 2020 to February 2021. Thus, in the same month of 2020 (June), the plant received the highest rainfall, and the decreases continued until the end of the cropping pattern. Hence, January 2021 had the lowest rainfall received by the plant.

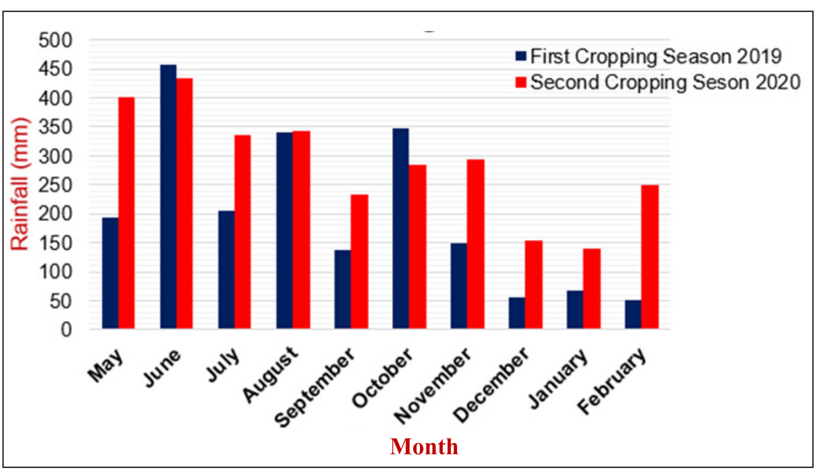

Figure 1. Mean monthly rainfall (mm), May 2019 - February 2021

Crop Management and Harvesting

Land Preparation

The experimental area between coconut trees spaced 10 × 10 meters was plowed twice using the animal-drawn moldboard plow and harrowed once before planting. This provided good soil condition and tilth for root development and minimized the weed problem. Furrows were prepared one meter away from the coconut trees with a spacing of 60 cm and about 8 cm depth for corn, mung bean and sweet potato intercrops.

Planting of Sole Crops

A. Corn— The seeds were planted by sowing at a planting distance of 60 cm by 25 cm and covered with fine soil about 2 cm thick. Thinning was also done one week after planting, leaving only one plant per hill. At this time, the missing hills were replanted.

B. Mung bean—Planting was performed by sowing the seeds at a planting spacing of 60 cm by 25 cm. Sown seeds were covered with fine soil around 2 cm thick. Thinning was executed one week after germination, leaving only two plants per hill. Replanting of missing hills was simultaneously done with thinning.

C. Sweet potato—Vine cuttings around 25 cm in length were secured. These were planted in beds spaced at a planting distance of 60 cm by 25 cm with one cutting per hill. Prior to planting, defoliation was done on each stem cutting to prevent over-transpiration in the field. In planting, two-thirds of the cuttings were buried in the soil and then covered with soil. The replanting of missing plants was done two weeks after planting.

Planting of Intercrop Mixes

A. Corn + Mung bean—The replacement method was used for intercrops with a planting ratio of 1:1. Each plot had seven rows of mung bean and six rows of corn in an alternate arrangement. Planting was done by sowing the seeds on the furrows at 60 cm by 25 cm spacing and covering them with 2 cm thick soil. Thinning was done one week after germination, leaving only one plant per hill for corn and two plants for mung bean. The missing hills for both crops were replanted at the same time.

B. Corn + Sweet potato—A replacement method was used with a planting ratio of 1:1. The plot had seven rows of sweet potatoes and six rows of corn in an alternate arrangement. Corn was planted by sowing the seeds on the furrows, whereas sweet potato cuttings were buried on the bed at least two-thirds of its length. They were spaced at 60 cm by 25 cm and covered with a 2 cm thick soil. For corn, thinning was done after one week, leaving only one plant per hill. On the other hand, replanting missing hills for corn was performed during that time. However, sweet potato was replanted two weeks after planting.

Fertilization

Based on the soil analysis results, the entire experimental site was applied with vermicast. The sweet potato recommended rates of three tons per hectare were used in the study, with 8.4 kg per experimental plot. The vermicast was applied during the final harrowing of the area to incorporate the organic nutrient source into the soil. It was done one week before planting. No organic fertilizers were applied in the next cropping.

Weed Management

The experimental area was weed-free through regular hand weeding operations to minimize competition between the plants and weeds for moisture, nutrients and other field resources. Hand weeding started two weeks after planting, depending on the weed density in the area. Manual hilling-up for sole and intercrops was done at 30 DAP. Further, spot weeding was done as often as necessary.

Pest Management

Insect pests and disease infestations were observed by cropping pattern per cropping season. Fermented Kakawati leaves were applied during the vegetative stage of the first cropping to control cutworm insect pests. Proper monitoring was taken into action as often as necessary until the crops reached maturity.

Water Management

The soil moisture was monitored during the critical stages of growth and development (germination, vegetative, flowering and pod/seed filling stages) of the crops.

Harvesting

A. Corn ears were harvested 103 days after sowing when the grains matured, as indicated by glazed kernels and 90% browning of the leaves. The harvested ears were shelled and sundried until 14% moisture content was attained.

B. Mung bean pods were harvested 60–80 days after sowing when they were brown or black, and as soon as 75% of the pods dried up. Priming was done every three days for at least three priming. Harvested pods were placed in a net bag before sun drying to facilitate easy threshing. The beans were sundried to 12% moisture content for safe storage.

C. Sweet potato fresh roots were harvested 153 DAP (5 months) on the first cropping and 294 DAP (10 months) on the second cropping. When fleshy roots reached the desired size and passed the maturity test, they were cut crosswise and exposed to the air. When the cut surface dried up, the roots were already mature, but when sap still flowed, this meant these were immature. All harvested roots were graded as marketable and non-marketable based on a set of criteria.

Criteria	Marketable Fleshy Root	Non-marketable fleshy roots
Root Length	At least 10 cm, uniform length	Very variable, slender
Root diameter	At least 4 cm, uniform diameter	Very variable, rough
Shape	Long to oblong	Various shape
Smoothness	Smooth to rough	Generally rough
General	Generally free from blemishes	Damaged, very badly bruised and diseased

Data Gathering Procedure

Growth and Yield Parameter for Corn

Days to emergence were taken when 80% of the seeds sown in a plot had emerged or germinated. The plant height (cm) was measured at harvest maturity with a meter stick. The plant height was measured from the base of the plant to the tip of the flag leaf of 10 representative sample hills per plot. Days to tasseling were taken from sowing up to when 80% of the plants in the plot had tassels. Days to silking were determined from the date of sowing up to when at least 80% of the plants per treatment had a 3 cm length of silk. Ear height (cm) was measured by measuring the distance of the ear node from the ground using ten representative samples per treatment. The yield and yield components were obtained. The weight (g) of 1000 seeds was obtained by weighing 1000 randomly selected seeds from each treatment. The shelling percentage was determined by weighing the shelled grains from ten randomly selected ear samples divided by the weight of unshelled ears multiplied by 100. The grain yield (kg/ha) was obtained from the seven data rows in each plot and expressed in kilograms per hectare (kg/ha). Grain yield was adjusted to 14% Moisture Content (MC) using the formula:

$$\text{Grain yield (kg/ha)} = \frac{\text{Plot yield (g)}}{\text{1,000 g/kg}} \times \frac{\text{10,000 m}^2\text{/ha}}{\text{Effective harvest area (EHA) (m}^2\text{)}} \times \frac{100 - \text{MC}}{86}$$

where, EHA = Effective harvest area, 8.4 m^2.

Growth and Yield Parameter for Mung Bean

Days to emergence were taken when 80% of the seeds sown had emerged in each plot. The number of days to flower was recorded from planting to when at least 50% of the plants per treatment flowered. The plant height (cm) was measured at harvest maturity. Plant height was measured from the base of the plant to the tip of the leaf for 10 representative sample hills per plot using a meter stick. The days to maturity were taken at harvest based on the days from sowing to the first priming when 80% of the pods in a plot were turned brown or black. The yield and yield components were obtained. The pod length (cm) was based on the average length of 10 randomly selected pods from ten sample plants per treatment. The number of seeds per pod was determined by counting the number of seeds of 10 randomly selected pods from ten sample plants per treatment. The weight (cm) of 1000 seeds was obtained by weighing 1000 randomly selected seeds from each treatment using a triple beam balance. The bean yield (kg/ha) was obtained from the seven data rows in each plot and expressed in kilograms per hectare (kg/ha). The grain yield was adjusted to 12% MC using the formula above.

Growth and Yield Parameters for Sweet Potato

The length (cm) of the main vines was measured from the base to the tip of the vines of ten sample plants per treatment taken at harvest using a meter stick. The number of lateral vines was taken from the same sample plants per treatment taken at harvest. Days to maturity were recorded from the time of planting to the harvesting of fleshy roots. The yield and yield components were obtained. The length (cm) and diameter (cm) of marketable fleshy roots were taken from ten randomly selected fleshy roots of ten sample plants per treatment. The number of marketable fleshy roots was determined by counting all marketable fleshy roots from ten sample plants per plot. Weight (kg/ha) of marketable fleshy roots was determined by weighing the same marketable fleshy roots from the seven data rows and computed on a per hectare basis as follows:

$$\text{Weight of marketable fleshy roots (kg/ha)} = \frac{\text{Plot yield (g)}}{1{,}000 \text{ g/kg}} \times \frac{10{,}000\text{m}^2/\text{ha}}{\text{EHA (m}^2)}$$

where, EHA = Effective harvest area, 8.4 m^2.

Further, the percentage of marketable fleshy root. It was determined by converting the data obtained from the number of marketable fleshly roots and computed as follows:

$$\text{Marketable fleshy roots (\%)} = \frac{\text{No. of marketable fleshy roots}}{\text{Total number of fleshy roots}} \times 100\%$$

While the number of non-marketable fleshy roots. It was determined by counting all non-marketable fleshy roots from the same sample plants per plot. Then, the weight (kg/ha) of non-marketable fleshy roots. It was determined by weighing the same non-marketable fleshy roots from the seven data rows and computed on a per-hectare basis:

$$\text{Weight of non-marketable fleshy roots (kg/ha)} = \frac{\text{Plot yield (g)}}{\text{1,000 g/kg}} \times \frac{\text{10,000m}^2\text{/ha}}{\text{EHA (m}^2\text{)}}$$

where, EHA = Effective harvest area, 8.4 m^2.

The percentage of non-marketable fleshy roots was determined by converting the data obtained from a number of non-marketable fleshy roots and computed as follows:

$$\text{Non-marketable fleshy roots (\%)} = \frac{\text{No. of non-marketable fleshy roots}}{\text{Total number of fleshy roots}} \times 100\%$$

Productivity Measurements

The total yield equivalent (PHP) was determined by adding the main crop and the intercrop yield. Further, the economic profitability was computed with the cost. The return of the experiment per treatment was computed to measure the Return on Investment (ROI), and this was calculated using the formula:

$$\text{ROI} = \frac{\text{Net income}}{\text{Cost of production}} \times 100$$

Statistical Analysis

Agronomic characteristics, yield performance, productivity and profitability of corn, mung bean, and sweet potato were gathered. After collecting and tabulating, data were analyzed using statistical Analysis of Variance (ANOVA) in RCBD using Statistical Tool for Agricultural Research (STAR) software version 2.0.1. The Honestly Significant Difference (HSD) test determined significant differences among treatments.

RESULTS AND DISCUSSION

Agronomic and Yield Performance of Corn

Growing corn in cropping patterns resulted in varying plant and ear heights at maturity. The plant and ear heights of corn were significantly influenced by the placement of the crop in the pattern (Table 1). Plant height was generally shorter at 185.30–216.78 cm for corn grown from October 2019 to January 2020 (first cropping) compared to corn grown from May to August 2020 (second cropping) with 214.63–242.43 cm plant heights. The shortest plant height of corn was observed in CP4, Corn + Sweet potato-mung bean, with 185.30 cm. It may be due to competition between the corn and sweet potato components for Nitrogen.

There was no significant difference in plant height for corn planted in sole cropping or intercropping with mung bean within the same season at alpha 0.05 because lone corn cropping offers sufficient nutrition to the corn as there is no nutrient competition. Although the mung bean's capacity to fix nitrogen, which contributes N to the neighboring corn plants, causes a relatively small increase in the mean plant height of corn interplanted with it. As per the findings of Gong et al. (2021), the intercropping system's heightened competition facilitates the mung bean's capacity to enhance the biological fixation of nitrogen, propelling the intercrops' growth. This benefit of using atmospheric and complementing soil N for mung bean intercropping reduces competition for N nutrients (Balde et al., 2011).

However, the results showed that corn with sweet potato intercropping during the first cropping produced a significantly shorter plant height than corn planted in sole cropping or monocropping at the second cropping. Further, sole corn in the first and second cropping yielded no significant difference, yet higher means were observed in the second cropping after mung bean and sweet potato. This observation might be due to the changes in soil moisture relative to the amount of rainfall received, not directly to the effect of non-leguminous or leguminous cropping patterns.

The ear height of corn differed significantly in the cropping pattern. The same trend was observed with the plant height of corn in different cropping patterns. Ear height in corn planted from the first cropping was significantly shorter at 65.88–83.60 cm than in corn grown in the second cropping, with heights ranging from 96.0 –116.57 cm. No significant difference was observed in the ear height of corn planted in sole cropping or intercropped within the same cropping season. Intercropping of Corn + Sweet potato (CP4) had a significantly shorter ear height of 65.88 cm than corn planted in sole cropping or intercropping in the second cropping season. It confirmed the observation that sweet potato was a strong competitor for corn in terms of nutrients and available resources in the soil. Opposing to the result of the study by Goulart et al. (2011) indicated that sweet potato intercrop with sweet corn does not affect the height of sweetcorn.

Furthermore, the yield and yield components of corn, such as the weight of 1,000 seeds and the grain yield of corn in the cropping pattern grown under coconut, are presented in Table 2. There was a significant variation in the weight of 1000 seeds (268 to 270 g) as affected by cropping patterns. Both monocrop corn intercropped on the first cropping have a heavier grain than the corn produced in the second. In the cropping pattern, Corn + Mung bean (CP3) had heavier grains, 270 grams, in the first cropping. However, there was no significant difference in either sole corn or intercropping during the season. Corn planted on the second cropping showed no significant difference; thus, CP8, Sweet Potato-Corn + Mung bean, had heavier grains of 231.67 grams compared to corn sole and intercropped with sweet potato. Two cropping seasons determined that intercropping of Corn + Mung bean produced heavy grains in corn.

Table 1
Plant and ear height (cm) at maturity of corn under coconut in various cropping patterns

Treatment	**Cropping patterns**		**Plant height (cm)**	**Ear height (cm)**
	1st cropping	**2nd cropping**		
CP1	Corn	Mung bean	207.17ab	72.80bc
CP2	Corn	Sweet potato	216.38ab	83.60bc
CP3	Corn + Mung bean	Sweet potato	216.78ab	82.83bc
CP4	Corn + Sweet potato	Mung bean	185.30b	65.88c
CP5	Mung bean	Corn	229.37a	108.50a
CP6	Sweet potato	Corn	242.43a	116.57a
CP7	Mung bean	Corn + Sweet potato	214.63ab	96.00ab
CP8	Sweet potato	Corn + Mung bean	240.83a	110.13a
F- Test			**	**
% CV			5.75	9.07

Note. Means with the same letter(s) are not significantly different by least significant difference, $p \geq 0.05$, based on the Honestly Significant Difference test; ** = significant at $p \leq 0.01$

Table 2
Weight of 1,000 seeds and grain yield of corn under coconut in various cropping patterns

Treatment	**Cropping patterns**		**Weight of 1,000 seeds (g)**	**Grain yield (kg/ha)**
	1st cropping	**2nd cropping**		
CP1	Corn	Mung bean	268.33a	2176.60ab
CP2	Corn	Sweet potato	251.67ab	2855.17a
CP3	Corn + Mung bean	Sweet potato	270.00a	2345.27ab
CP4	Corn + Sweet potato	Mung bean	241.67abc	1115.10b
CP5	Mung bean	Corn	225.00bc	2948.42a
CP6	Sweet potato	Corn	218.33c	3067.47a
CP7	Mung bean	Corn + Sweet potato	211.67c	1281.75b
CP8	Sweet potato	Corn + Mung bean	231.67bc	2400.80ab
F- Test			**	**
% CV			4.68	22.90

Note. Means with the same letter(s) are not significantly different by least significant difference, $p \geq 0.05$, based on the Honestly Significant Difference test; ** = significant at $p \leq 0.01$

The cropping pattern significantly influenced the grain yield of corn per hectare. Thus, corn planted on the second cropping produced a higher grain yield at 2948.42–3067.47 kg/ha than corn grown on the first cropping. Corn planted in the first season showed significant differences among patterns. Two sole corn and corn intercropped with mung bean yielded 2176.60–2855.17 kg/ha, but when corn was intercropped with sweet potato, the yield of corn was reduced. After mung bean, corn was observed to be higher because leguminous crops such as mung bean would help to nurture and replenish the soil (Arangote et al., 2022; Rani et al., 2019). The lowest grain yield was observed in CP4 (Corn + Sweet potato-mung bean) at 1115.10 kg/ha, comparable to Corn + Sweet potato planted after mung bean (CP7) at 1281.75 kg/ha. These values were significantly lower than corn in either sole or Corn + Mung bean intercropping. Altogether, 1000 grains of corn are greater in the first season compared to the second season, but the yield of corn is greater in the second season compared to the first season. This might be due to the number of grains. Some factors like cropping placement, mono or intercropping pattern, and their respective influence on soil condition, fertility, and rainfall received each cropping period. Besides, inter-specific competition between plants for above- and below-ground growth variables, such as soil moisture, nutrients, space, and solar radiation, may cause yield differences (Khan et al., 2012; Syafruddin, 2020). Similar data observed the oppositeness on the result of means in terms of 1000 grain weight but lower yield and higher yield but lower in 1000 grain weight because of the ecological factors and treatment (Musahraf et al., 2013; Nasar et al., 2023).

It confirms the study of Islam et al. (2014) that the intercropping of regular corn row + 1-row sweet potato yields 2.3 tons/ha compared to sole corn, which yields 5.2 tons/ha. It implies that corn intercropped with mung bean produced the exact outcome of sole corn, while corn intercropped with sweet potato has a low corn grain yield. Opposing the result of Johnson and Gurr (2016), rice, finger millet, maize, and pigeonpea yield was higher when intercropped with sweet potato compared to sole crops. Amaya et al. (2021) added that the presence of sweet potato in the planophile improves the intercrops yield.

Agronomic and Yield Performance of Mung bean

The cropping patterns significantly influenced the plant height of mung beans (Table 3). The mung bean from the first cropping is shorter at 58.33–64.93 cm than the second at 78.43–85.07 cm. The plant height of mung bean planted after Corn + Sweet potato during the second cropping exhibited the tallest plant height at 85.05 cm. Although taller plants were observed during the second cropping (78.43–85.07 cm), the results show no significant difference from those planted in the first cropping. However, the shortest heights were observed at 58.33–59.80 cm in cropping patterns. CP3 and CP5 (first cropping) were significantly lower than CP4 (second cropping). No difference was observed when mung beans were planted in sole or intercropping. The bean yield of mung beans was significantly different among cropping patterns. Planting sole mung bean as the first crops (CP5 and CP7) produced the highest yield at 277.77–363.13 kg/ha over mung bean intercropped with corn (CP3). These mung bean yields were significantly higher than those planted in varying crop patterns during the second cropping. The second cropping of mung bean increases once compared with the cropping pattern of sole corn followed by mung bean (CP1) and

(CP4) Corn + Sweet potato; this might be due to the improved aeration of soil condition in cultivation with sweet potato. This result might be affected by the environmental condition. Bean yield increment on the first cropping was due to favorable climatic conditions; thus, the rainfall affected the second copping. According to Ro et al. (2023), the mung bean, as drought-resistant in nature, cannot tolerate excess water. Mung bean requires relatively less water than other legumes for good growth and production. Nevertheless, no significant difference was observed when mung beans were planted in sole and intercropping within the season (Parida & Das, 2005). Mung bean intercropped with corn has a lower yield than sole mung bean, particularly on the first cropping, but almost the same on the second cropping, considering there was another yield from the companion crop. In conformity with this result, Alemayehu et al. (2018) found significant differences among seed yields of common bean varieties in maize + common bean intercropping. Likewise, Bekele et al. (2016) proved that grain yield per hectare of soybean was significantly affected by maize + soybean intercropping. In line with the result, Nasar et al. (2023) stated that intercropping reduced the mung bean yield by 28% compared to sole cropping of mung bean in maize + mung bean intercropping. Similarly, Arshad et al. (2020) obtained a significantly highest grain yield of sole mung bean in maize + mung bean intercropping.

Table 3
Plant height and bean yield of mung bean under coconut in various cropping patterns

Treatment	**Cropping patterns**		**Plant height (cm)**	**Bean yield (kg/ha)**
	1st cropping	**2nd cropping**		
CP3	Mung bean + Corn	Sweet potato	59.80^{b}	119.07^{b}
CP5	Mung bean	Corn	58.33^{b}	277.77^{a}
CP7	Mung bean	Corn + Sweet potato	64.93^{ab}	363.13^{a}
CP1	Corn	Mung bean	79.97^{ab}	89.29^{b}
CP4	Corn + Sweet potato	Mung bean	85.07^{a}	105.16^{b}
CP8	Sweet potato	Corn+ Mung bean	78.43^{ab}	71.43^{b}
F- Test			**	**
% CV			11.51	25.59

Note. Means with the same letter(s) are not significantly different by least significant difference, $p \geq 0.05$, based on Honestly Significant Difference test; ** = significant at $p \leq 0.01$

Agronomic and Yield Performance of Sweet Potato

The length of the main vine and the number of lateral vines of sweet potato are presented in Table 4. The length of the main vine of sweet potato shows no significant difference in the cropping pattern. The main vine was generally shorter at 378.47–416.28 cm for sweet potato grown on the first cropping than the second cropping with 429.7–485.7 cm length. The shortest main vines of sweet potato were recorded in CP6 (Sweet potato-Corn) with

378.47 cm, while the longest vine was also recorded in CP7, sweet potato intercropped with corn previously planted with mung bean with 485.7 cm. The vines that were the length of the sole sweet potato intercropped with corn did not vary in the two cropping seasons.

A significant influence in the number of lateral vines was observed in the cropping pattern. Sweet potato intercropped with corn (CP4) shows significantly more lateral vines of 6 compared to the other cropping patterns in two seasons except for the sole sweet potato of CP8 (Sweet potato-Corn + Mung bean), which had five lateral vines. The sweet potato planted on the first cropping has a more substantial number of lateral vines, with 4–6 than the sweet potato planted on the second cropping, with 3–4 vines. Moreover, sweet potato intercropped to corn as the first crop has significantly more vines compared to sole sweet potato (CP4). No significant difference was observed during the second cropping, either sole or intercropped.

Table 4
Length of main vine and number of lateral vines of sweet potato under coconut in various cropping patterns

Treatment	**Cropping patterns**		**Length of the main vine (cm)**	**No. of lateral vines**
	1st cropping	**2nd cropping**		
CP4	Sweet potato + Corn	Mung bean	388.07	6^{a}
CP6	Sweet potato	Corn	378.47	4^{b}
CP8	Sweet potato	Corn + Mung bean	416.28	5^{ab}
CP2	Corn	Sweet potato	459.70	4^{b}
CP3	Corn + Mung bean	Sweet potato	429.70	3^{b}
CP7	Mung bean	Sweet potato + Corn	485.70	3^{b}
F- Test			ns	**
% CV			15.69	16.32

Note. Means with same the letter(s) are not significantly different by least significant difference, $p \geq 0.05$, based on the Honestly Significant Difference test; ** = significant at $p \leq 0.01$; ns = Not significant

Yield and Yield Components of Sweet Potato

The length, diameter and weight of marketable fleshy roots are presented in Table 5. The data revealed a significant influence on the size of marketable fleshy roots of sweet potatoes. The longest marketable roots of 13.39 cm were in CP6 (Sweet potato-Corn). It is significantly longer than the roots harvested in the second cropping in sole and intercrop sweet potatoes. However, CP6 did not differ from the other pattern planted on the first cropping. Sweet potato-Corn has a 13.39 cm length of roots, while CP2, Corn-Sweet potato has the shortest root length of 10.89 cm.

The sweet potato alone did not show significant variation among the sweet potato intercropped with corn. It implies that sweet potato with corn did not affect the length of the fleshy roots of sweet potato. The diameter of marketable fleshy roots did not vary among the cropping patterns. The sweet potato planted on the first cropping has a diameter of 5.65–6.37 cm, while roots harvested on the second cropping have a diameter range from 5–5.79 cm. The sole sweet potato produced in the first cropping has a slightly wider diameter from 6.04–6.37 cm than sweet potato roots planted from intercropping in the same season—both sole and intercropped sweet potato had grown on the second cropping. The diameter of sweet potato intercropping was slightly shorter than the roots produced from sole sweet potato. There was a significant variation in the weight of marketable fleshy roots. The sole sweet potato planted on the first cropping (CP6 and CP8) produced the highest root yields at 8684.55–10263.93 kg/ha compared to sweet potato intercropped with corn (CP4).

These marketable root yields were significantly higher than those sweet potatoes planted in varying cropping patterns during the second cropping. Sweet potatoes planted in the second cropping yielded low weight ranges from 2,111–3,484.13 kg/ha regardless of the plant previously planted. Among the possible factors that affected the yield of sweet potatoes were the rainfall and soil temperature. Generally, higher temperatures on the soil surface could be attributed to greater numbers of living organisms and greater biological activities. During the second cropping, the experimental site received more rainfall (Figure 1), resulting in high soil moisture and, subsequently, soil having a low temperature. Sweet potato is much less tolerant of excess water than of drought. It confirms the study of Han et al. (2014) that sweet potato is considered a drought-tolerant crop; during the rainy season, soils are saturated with water over days. Thus, this causes a decrease in the size and number of tuberous roots but increases the fresh weight of the shoots.

Table 5
Length, diameter, and weight of roots of sweet potato under coconut in various cropping patterns

Treatment	**Cropping patterns**		**Length roots (cm)**	**Diameter roots (cm)**	**Weight of roots (kg/ha)**
	1st cropping	**2nd cropping**			
CP4	Sweet potato + Corn	Mung bean	12.78ab	5.65	4621.05bc
CP6	Sweet potato	Corn	13.39a	6.37	10263.92a
CP8	Sweet potato	Corn + Mung bean	12.63ab	6.04	8684.55a
CP2	Corn	Sweet potato	10.89b	5.79	3484.13c
CP3	Corn + Mung bean	Sweet potato	11.06b	5.00	2111.11c
CP7	Mung bean	Sweet potato + Corn	10.96b	5.01	2271.83c
F- Test			*	ns	*
% CV			8.20	11.21	23.24

Note. Means with same letter(s) are not significantly different by least significant difference, $p \geq 0.05$, based on the Honestly Significant Difference test; * = significant at $p \leq 0.05$; ns= Not significant

Total Yield Equivalent

Table 6 presents the total yield and equivalent of corn, mung bean, and sweet potato in a cropping pattern grown under coconut. The total yield in the cropping pattern was determined by adding the main crop and intercrop yield in two cropping seasons. Results show that total yield had significantly varied among the different cropping patterns. The cropping pattern of sweet potato-corn (CP6) yielded 13,331.4 kg/ha and had considerably higher compared to the cropping patterns mung bean - corn (CP5), which obtained 3,226.19 kg/ha, Corn + Mung bean-Sweet potato (CP3) with 4,575.45 kg/ha, mung bean-Corn + Sweet potato (CP7) 3,916.71 kg/ha and corn-mung bean (CP1) that incurred the lowest total yield of 2,265.89 kg/ha. However, CP2 (Corn-Sweet potato), CP4 (Corn + Sweet potato-Mung bean), and CP8 (Sweet potato-Corn + Mung bean) show no significant difference among cropping patterns. The cropping pattern planted with sweet potato, either in the first or second cropping, showed a much higher total yield than corn and mung bean.

Table 6
Total yield and equivalent of corn, mung bean and sweet potato under coconut in various cropping patterns

Treatment	Cropping patterns		Total yield (kg/ha)	Total yield equivalent (PHP)
	1st cropping	2nd cropping		
CP1	Corn	Mung bean	2,265.89[c]	36,221[c]
CP2	Corn	Sweet potato	6,339.30[abc]	77,669[abc]
CP3	Corn + Mung bean	Sweet potato	4,575.45[bc]	61,053[bc]
CP4	Corn + Sweet potato	Mung bean	5,841.31[abc]	67,143[bc]
CP5	Mung bean	Corn	3,226.19[c]	55,337[bc]
CP6	Sweet potato	Corn	13,331.40[a]	148,651[a]
CP7	Mung bean	Corn + Sweet potato	3,916.71[bc]	56,470[bc]
CP8	Sweet potato	Corn + Mung bean	11,156.78[ab]	125,715[ab]
F- Test			**	**
% CV			41.96	32.45

Note. Means with same the letter(s) are not significantly different by least significant difference, $p \geq 0.05$, based on the Honestly Significant Difference test; ** = significant at $p \leq 0.01$

The total equivalent yield was data converted by multiplying the yield of each crop price and adding to the main crop of corn. The crop prices were corn at 15 pesos, mung bean at 40 pesos, and sweet potato at 10 per kilo, which is very low due to the high supply of the season. Results revealed highly significant differences among cropping patterns. The cropping pattern of sweet potato-corn (CP6) had a total equivalent yield of PHP 148,651, which was a significant difference from other cropping patterns except for the cropping pattern Sweet Potato-Corn + Mung bean (CP8) with the monetary amount of PHP 125,715 and CP2, Corn-Sweet potato with PHP 77,669 total yield equivalent. The result implies that total yield and equivalent were higher in cropping patterns planted with sweet potato, either sole or intercropped, due to its heavyweight characteristic. Thus, all cropping patterns planted with sweet potato outclass in overall total crop production.

Economic Profitability

The production cost and return analysis are presented in Table 7. Data shows that the cropping pattern Sweet potato-Corn + Mung bean (CP8) has recorded the highest crop production cost, amounting to 75,850 pesos, followed by all cropping patterns planted with sweet potato. Note that NSIC SP 30 sweet potato variety cuttings were brought from the Visayas State University (VSU), Baybay, Leyte, for 0.50 pesos per cutting. Nevertheless, CP6, Sweet potato-Corn got a gross monetary return of PHP 73,601 with an ROI of 98%, followed by the cropping pattern Sweet potato-Corn + Mung bean (CP8) with a net income of PHP 49,865 and ROI of 66%. Subsequently, cropping patterns of Corn + Mung bean-Sweet potato (CP3) had the lowest income and had no return. Return of investment values was high, according to the cropping pattern planted with sweet potato, either solely or intercropped on the first cropping. Thus, sweet potatoes and corn excel in all cropping patterns.

Table 7
Production cost and return analyses in various cropping patterns grown under coconut

Treatment	Cropping patterns		Total yield equivalent (PHP)	Production cost (PHP)	Net income (PHP)	ROI (%)
	1st cropping	2nd cropping				
CP1	Corn	Mung bean	36,221	42,600	(6,379)	-15
CP2	Corn	Sweet potato	77,669	75,050	2,619	3
CP3	Corn + Mung bean	Sweet potato	61,053	75,050	(14,797)	-20
CP4	Corn + Sweet potato	Mung bean	67,143	59,625	7,518	13
CP5	Mung bean	Corn	55,337	42,600	12,737	30
CP6	Sweet potato	Corn	148,651	75,050	73,601	98
CP7	Mung bean	Corn + Sweet potato	56,470	59,625	(3,155)	-5
CP8	Sweet potato	Corn + Mung bean	125,715	75,850	49,865	66

Note. Price of corn @ PHP 15.00/kg; Price of wholesale mung bean @ PHP 40.00/kg; Price of wholesale sweet potato @ PHP 10.00/kg

CONCLUSION

Based on the study's findings, the conclusions were that corn plants, ear height, and grain yield are best when corn is placed as the second crop in the pattern. However, Corn + Sweet potato intercropping results in a decrease in plant height and grain yield of corn. Mung bean plant height and bean yield are improved regardless of its placement in the cropping pattern, either in sole or intercropped with corn. Sweet potato has the best performance on root yields when placed as the first crop in the cropping pattern—however, sweet potato intercropping results in a reduction in yield. Therefore, provided by the ROI percentage, the cropping patterns of sweet potato followed by corn (CP6) and the same placement in the crop pattern of sweet potato followed by mutlicrop of Corn + Mung bean (CP8) showed the best performance and are recommended for the coconut farmers in Zamboanga del Sur.

ACKNOWLEDGEMENTS

The authors thank the Commission on Higher Education Philippines for supporting the dissertation grants under the K12 Transition Scholarship Program and the J.H. Cerilles State College.

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